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MANUFACTURING PROCESS IMPROVEMENT
By Using Lean Methods

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VALMISTUSPROSESSIN KEHITTÄMINEN Lean metodien avulla

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Opinnäytetyön tavoitteena oli selvittää, voidaanko Lean-menetelmien avulla luoda liiketaloudellisesti kannattava hanke, jonka avulla voidaan kehittää malliyrityksen tuotannon tehokkuutta.

Teoriaosassa käsitellään Lean filosofian keskeisimmät käsitteet, metodit ja työkalut käyttäen pääkohdin hyväksi alan johtavien asiantuntijoiden kirjallisuutta sekä Toyotan mallin mukaista Lean-ajattelumaailmaa. Teoriaosaan pohjautuen on valittu eri työkalut ja metodit tähän opinnäytetyöhön.

Käytännön osassa Lean-mallin implementointia tarkastellaan ensin benchmark-yritysten kautta saavutetuilla tiedoilla. Tämän jälkeen käsitellään malliyrityksessä vaadittu koulutusprosessi joka mahdollisti Lean ajattelumallin jalkauttamisen malliyrityksessä.

Tuotantoprosessia tarkastellaan aluksi kuvaamalla tuotantoprosessin nykytila arvovirtakartoituksen avulla. Arvovirtakartoituksesta saatuja tietoja verrattiin työohjeiden ja tuotantosuunnitelmien kautta suunniteltuun nykytilaan. Samalla käydään läpi 5S mallin sisäänajo ja sen vaikutukset.

Tutkimuksen tuloksena syntyi uusi layout malli joka pohjautui arvovirtakartoituksen nykytilasta laadittuun tahtotilaan sekä spagetti mallinnuksen tuomaan uuteen virtaavaan tuotantomalliin. Tuotteen arvoa lisäävä osuus kasvoi 24%, läpimenoaika parani 67% sekä poissaoloon johtavat tapaturmat poistuivat.

Tutkimuksen pohjalta oli mahdollista rakentaa kannattava liiketoimintasuunnitelma jossa oli mukana layout muutoksen, 5S implementoinnin sekä arvovirtakartoituksen tuottamat positiiviset vaikutukset.

”Tieto on jotain minkä voit hankkia rahalla. Viisaus on jotain minkä voit hankkia tekemällä.” Ohno, Taiichi

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The aim of this study was to determine whether Lean techniques can create a commercially viable project that improves the production efficiency of the case company Outotec (Ceramics) Oy

The theoretical part deals with Lean philosophy, the main concepts, methods and tools by utilizing the literature of the leading Lean experts, as well as Toyota way of Lean Thinking. The different tools and methods used in this thesis are based on this theory.

The practical part of the study looks first at how Lean implementation has been done in other companies by using benchmark visits. Furthermore this study will describe the required training process that allowed further Lean implementation in the case company.

The production process will be examined by using value stream mapping (VSM) to determine the current situation. This current situation value stream map data is then compared to the standard operation processed and to the planned current situation. Simultaneously this study goes through 5S model implementation and its implications.

As a result of this study a new layout model was created which was based on the value stream mapping and the flow production idea as well, which was created by using spaghetti modeling. The proportions of value add time of the production process increased to 24%, the lead-time improved by 67% and the lost-time injuries were removed.

Based on the study, it was possible to build a viable business case which included a layout change, a 5S project as well as a value stream mapping of the effects produced.

“Knowledge is something you buy with the money. Wisdom is something you acquire by doing it.” Ohno, Taiichi

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TERMS AND ABBREVIATIONS

TPS	Toyota Production System
Gemba	Japanese: the place where work actually happens
Jidoka	Autonomation
JIT	Just-In-Time
WIP	Work-In-Process
Kaizen	Continuous Improvement
VSM	Value Stream Mapping
Muda	Japanese term for “waste”
Mura	Japanese term for “Unevenness”
Muri	Japanese term for “overburdening”
BVA	Business value adding - activities
(NNVA)	Necessary but Non-Value Adding -activities
NVA	Non-Value Adding -activities
VA	Value Adding –activities
TPM	Total Productive Maintenance
Yoka-Poka	Error (Mistake) Proofing
OEE	Overall Equipment Effectiveness
Takt Time	Pace of customer demand rate
PDCA	Plan – Do – Check - Act

1 INTRODUCTION

In the introduction, the researcher will show from what basis this study has been created, for what purpose this study this for and what is the framework for this study.

“Weakened economy in emerging markets, further amplified by significant devaluation of currencies, political instability in some key markets, and concerns about the sustainability of China's growth, are dragging the market down despite some recovery in US and European economies. We are prepared to take further actions to adjust our costs in line with possibly continuing weak order intake and subsequent lower sales. In a cyclical industry we need to balance our actions to be well positioned for the eventual upward turn of the cycle." (Outotec Interim report, 2014).
This introduction from the interim report of Q1 2014 of Outotec by the president and CEO Pertti Korhonen was the outcome of economy slowdown which started in 2013.

According to IMF, growth in the emerging market and developing economies is expected to increase to 5.1 percent in 2014 and to 5.4 percent in 2015 while the euro area is turning the corner from recession to recovery. Growth is projected to strengthen to 1 percent in 2014 and to 1.4 percent in 2015. So the emerging markets and developing economies create more competitors to markets and usually with a much lower price.

On top of this, Finland is facing a unique workforce issue in the near future since a large number of workforce is retiring within the next ten years. According to OECD, Finland’s old-age dependency ratio (population aged 65 and over as a proportion of the population aged 20-64) is projected to increase from the 25% in 2000 to 43% in 2025 compared with an OECD average of 22% in 2000 and 33% in 2025. (OECD, 2010.)

For Outotec, one solution has been the introduction of O'Lean. O'Lean means a new way of working for all Outotec manufacturing sites. O'Lean is a way of doing things by implementing Lean methods.

1.1 The purpose of this study

Outotec (Ceramics) Oy has a long history of manufacturing high tech ceramics. The company took its first steps in 1918 under the name of Teknillinen Porsliinitehdas. The company moved to the current premises in 2000.The first manufacturing layout was drawn by using old equipment which was transferred from the old factory. Since the floor space of the old factory was significantly larger, a new layout was constricted. The available manufacturing floor space was 2500m2. From there, the company has grown first in 2005 by adding 1500m2 and again in 2009 by adding 1600m2 manufacturing floor space. So, by the end of 2009 the plant was producing more than 200 different ceramic parts in a 5600m2 space. By the end of 2012 the company made a decision to focus on Outotec products only and to cut off production of all other products. The reasons behind this decision were the shortcoming investment needs to replace old equipment which was not safe to operate and additionally the cost efficiency was at a poor level. This meant that many old workstations were scrapped and that led to a situation where remaining workstations were not properly located and production was ineffective. (Outotec (Ceramics) Oy company presentation, 2014.)

At the same time, markets indicated that competition had increased and there was a clear need to respond to market change. As a result, Outotec (Ceramics) started manufacturing cost mapping to look for areas were the company could gain savings.

Thirdly, Outotec launched the O'Lean project started in 2013 and Lappeenranta site was agreed to work as a pilot plant.

When all the situations above occurred closely in time, it was clear that current manufacturing needed to be measured, analyzed and improved systematically. All this was linked together with O'Lean.

This study aims to find an answer to the following primary question: How much can the current way of working be improved by using Lean approach and can a solid business case be created?
The secondary research questions which will create focus to the research are:

1. What is the share between value adding and non value adding work and how much can the share of value adding work be expanded?
2. How much can the waste of transportation and motion be reduced?
3. What are the bottlenecks and how to eliminate them?
4. Can single piece flow be achieved?

1.2 Theoretical framework

The study is based on Lean principles, methods and tools which are all described in more detail in part 2. VSM (Value Stream Mapping) is in the key role. Some other concepts like Spaghetti diagram and 5S are also applied to this study. These methods are chosen by the reason that this is the approach that O'Lean and also many other sources supports, like James Womack and Mike Rother. VSM gives the best big picture of how a process is works.

A brief pre-study was conducted at the plant to map out quickly what the most evident types of waste (waste is non value adding work or activity) were. Transportation, motion, defects and over-processing were listed as top waste categories.

Several researches have been made on similar subjects. Direct implementation of the previous works cannot be made since these researches are case dependent. Womack and Jones used tree different cases to show how Lean implementation can be done (Womack & Jones, 2003). A simple Lean implementation case was made with a company called Lantech and this can be considered as the closest one to Outotec (Ceramics) situation.

At Lantech they first started to think about value and how value is created in production line. Secondly, the current batch type work was made to flow. That meant that the production lines needed to be re-designed to accomplish flow. Spaghetti diagrams were used to visualize how a product was moving across the manufacturing process. This created the need to change the factory layout. Womack and Jones found out that this activity of moving production lines didn't involve massive investments. The flow freed up employees from the production to make the changes. All this was done in a six month's time. This can be a harder task than what Womack and Jones describe. Usually this type of change requires qualified persons and might even need permissions from the authorities. Safety issues also need careful consideration which has not been taken into account in this Lantech case as much as they should have. (Womack & Jones, 2003.)

As the next step, Lantech implemented Lean techniques such as standard work to reduce variation and waste of defects, Takt time to avoid fire fighting and visual control to show everyone what was going on.

All the three cases follow a similar path from value to continuous improvement. Since the scale of these companies grows from Lantech to Wiremold to Pratt & Whitney, the need to add more people who drive Lean implementation came clearer. Also, the concept Lean Enterprise, which involves everyone in value stream, was introduced. This meant that larger companies needed to involve subcontractors and even their subcontractors to Lean thinking in a way that the concept of value follows through the Lean Enterprise. (Womack & Jones, 2003.)

Ruag Space is the largest European space product supplier. Ruag Space Ab is Swedish subsidiary which produces microwave and digital products for space industry. Ruag space Ab has started to implement Lean in 2004 for production and in 2008 for production development.

The following example of the Ruag Space Ab Lean adoptation shows that all Lean implementations do not benefit immediately. Ruag used Lean methods like improvement board, Visual management, Value Stream Mapping, Local wiki and continuous learning. The aim was to reduce delivery time accuracy which was approx. 55% in 2004. In 2007, the company managed to deliver on-time 92% which was a significant improvement. By 2008, when Lean was implemented to product development department, this change affected to the delivery time accuracy so that it dropped 2009 to 80%. (Malmborg, 2012). This example shows that any change, no matter in which part of the value chain it is made, has an effect to the total process. If the on-time delivery had been one of the bonus criteria of manufacturing, they would not have been happy to see the effect of Lean implementation at the product development department.

In the example, A study of Applicability of Value Stream Mapping (VSM) in the Apparel industry in Sri Lanka, Mr Silva tested VSM in textile industry. According to Mr. Silva, modern managers find it difficult to identify the key areas and practices which can be used to eliminate waste in their processes (IJLT, 2012). VSM could be successfully implemented to apparel industry as the initial step of waste identification.

Continuous improvement and a strive to perfectionism are in the heart of Lean. As Belokar, Kumar and Kharp concluded their research, VSM have been proven to be a greatly useful tool to eliminate some waste in a cycle and find that there is more waste for you to eliminate in next cycle, during which lean becomes a habit or culture. (IJITEE, 2012.)

1.3 Research plan and methods

Dawson (2009) states that for quantitative data analysis, issues of validity and reliability are important. The researcher acknowledges the fact that during the measurement phase, at first, there may be some variation in data, but since data gathering has been conducted several times for one process step, the measured data is reliable for that snapshot of time and activity. All variables may cause deviation, like power cuts, which are not normal daily activities, have been taken into account and a new measurement is scheduled.

The researcher thinks that this is well in line with VSM process and therefore this quantitative research method is acceptable.

Qualitative research method is, on the other hand, a very personal process (Dawson, 2009). The researcher thinks that from this point alone, a qualitative research method cannot be used for this study. The aim of this study is to gain information which is measurable and comparable.

Furthermore, Dawson states that different processes are involved during qualitative data analysis (Dawson, 2009). First the collected data needs to be considered though the collection process. Secondly, value of the collected data needs to be evaluated. Thirdly, as research progresses, the collected data needs to be interpreted in a way that everyone knows what is going on. Last the mechanical process of analyzing the data needs to be conducted..

The researcher thinks that this is well in line with secondary research case which involves information and data collected from interviews.

The research plan is to map out the current situation by using VSM, process stamping and spaghetti diagram. All process steps will be measured and all workers are interviewed during the measuring phase. The measured numeric case-study data consists of the time that the operator uses daily in his/her job. The walking/transporting distance will also be measured.

Because only a few instances are normally studied, the case researcher will typically uncover more variables than there are data points, making statistical control impossible. Like Carson (2013) states, the purpose is to uncover non visual defects from the process and list all these type of defects which are taken into account during VSM process.

According to Gilgun (2011), case study research is valuable because of its contribution to theory. Without reference to theory, case studies provide anecdotal information. In other words, case studies only have value in relationship to currently held understandings and practices. In this study the researcher thinks that this study is clear example of case study research since results are linked to Lean methods and theory.

This study consists of a primary research case and a secondary research case. The primary research case is a quantitative case study where processes are “recorded” as they are carried out. The main focus is to map all data such as consumed time, walking distances etc. All data are used to taking a snapshot of one process at a specific time.
A secondary research involves interviews and comments from the operator or the process auditor. The data needs to be treated by using qualitative research methods since data consist personal thinking and opinions.

Measuring is carried out manually during normal workday and at the same time the observer writes down all different steps that the operator takes. During this, the observer takes notes when some improvement ideas come up.

Process stamping is carried out along with VSM measurement phase. The purpose is to map out all steps inside each process phase. This way every activity can be can be categorized as VA, NVA or BVA.

A Spaghetti diagram is used to determine the efficiency of current layout and in design phase of the new layout. The spaghetti diagram is to map out how a product moves through the value stream.

Process capability calculation is also carried out for selected products. This is to determine all possible bottlenecks.

Deductive reasoning is used to create the future state from the measured current situation. As this is a case study, the results cannot be copied and adopted to any other case.

2 WHAT IS LEAN?

This chapter gives a short presentation of Lean. The purpose is not to go deep into this subject but to give the reader basic understanding to follow the study all the way.

2.1 The definition of the term Lean

Usually, Lean (Lean manufacturing, Lean production, Lean enterprise) is linked to Toyota production system (TPS). There is no precise way to describe what Lean actually is since modern Lean manufacturing consists of many different tools to adopt and the level of adaptation varies from company to company. It could even be said that Lean has been around since the beginning of time because one of the key elements is to preserve value with less work and learn both from mistakes and people.

The term Lean was first introduced by John Krafcik who worked for MIT as a researcher. Krafcik used words Fordism and TPS to describe different production systems.

Rather than continuing to refer to the different paradigms such as resent Fordism and TPS, I would like to introduce two new terms here, Buffered and Lean production systems. Krafcik (1988) based these two new terms on the facts that western producers have a lot of Just-In-Case buffer stocks. Then he compared the western way to the Toyota way and found out how it was possible to achieve flow, better quality by minimizing buffer stocks.

In short, Lean provides a way to do more and more with less and less, while coming closer and closer to providing customers with exactly what they want (Womack & Jones, 2003). What the customer wants equals to what the customer values and therefore value is one of the key elements, too..

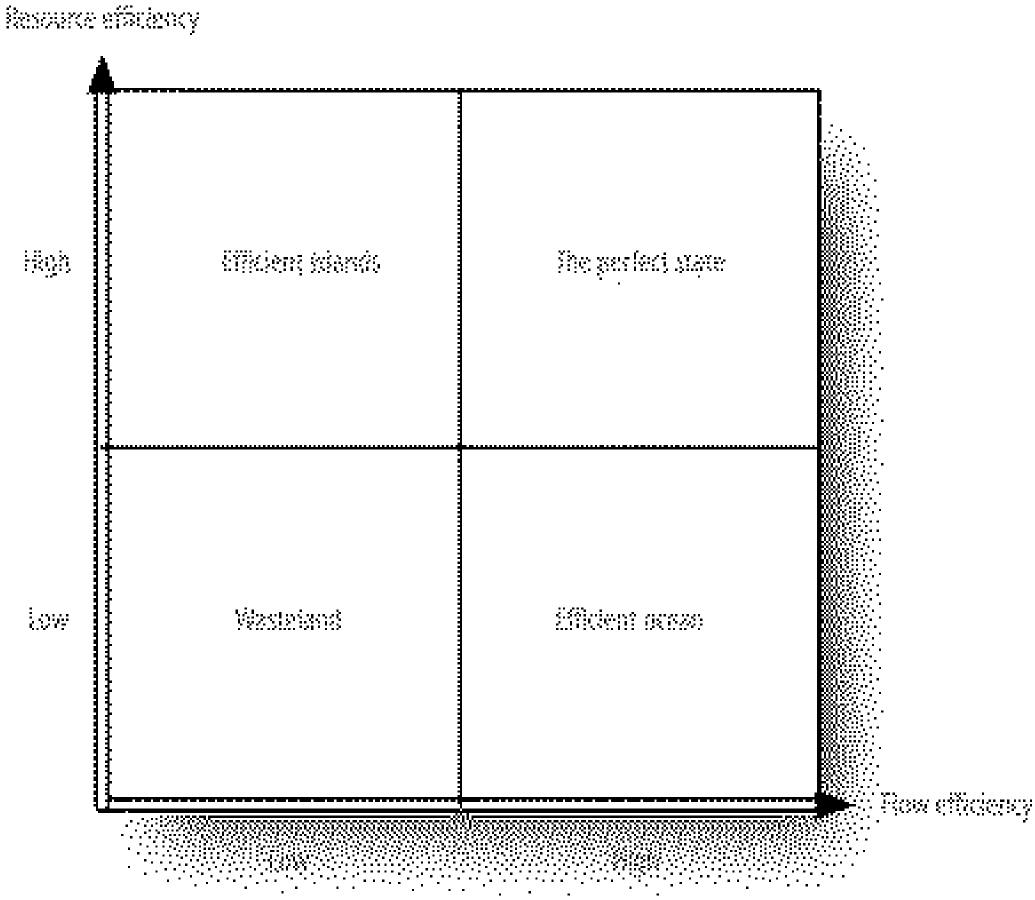
As is shown in part 3 of this study, a lot of Lean tools and methods exist, but in the end Lean is 20% about the tools and 80% about the people. (Torkkeli, 2013.)

As Torkkeli state, Lean is merely about tools, it is about thinking. Every single member of the organization needs to accept and adopt Lean and start to think better ways to get things done.

We need to think about our work, we need to experiment with new ideas, and we need to learn from these experiments. This is the Lean way. Tools are about how, but thinking is about why! Without knowing why you would implement Lean, the how will never be sustained. (Martichenko, 2012.)

A different approach was introduced by Mogid and Åhlström (2014) by pointing out that Lean means actually transformation from traditional efficiency of resource efficiency which involves utilizing resources as much as possible to a combination of recourse efficiency and flow efficiency. Modig and Åhlström described how flow efficiency concerns the share of the value adding activities in relation to the throughput time.

Lean is an operational strategy that prioritizes flow efficiency over resource efficiency. In other words, lean is a strategy for moving “to the right and up” in the efficiency matrix (picture 1). (Modig & Åhlsrtöm, 2014.)



Picture 1. The efficiency matrix (Modig & Åhlström, This is Lean: Resolving the Efficiency Paradox, 2014)

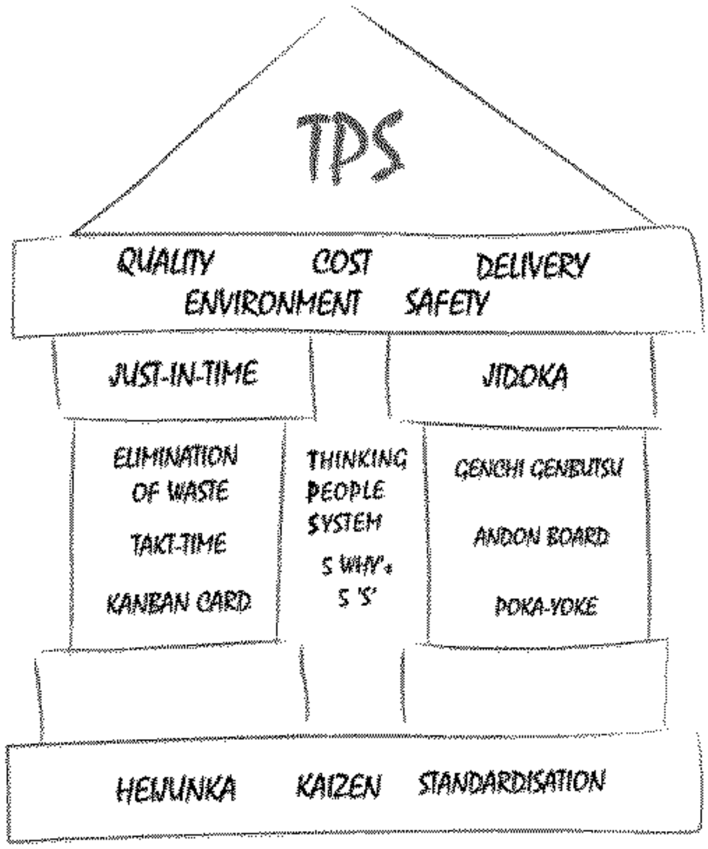
For most cases, it is easy to see Lean tools as visual management, 5S adopted, but this is just the tip of the ice berg. Rother describes all these visible tools as built upon invisible management thinking and routines.

Practices Tools Principles **(Visible)**

Management thinking and routines **(Invisible)**

Picture 2. Rother view of underlying logic of Lean (Rother, 2010)

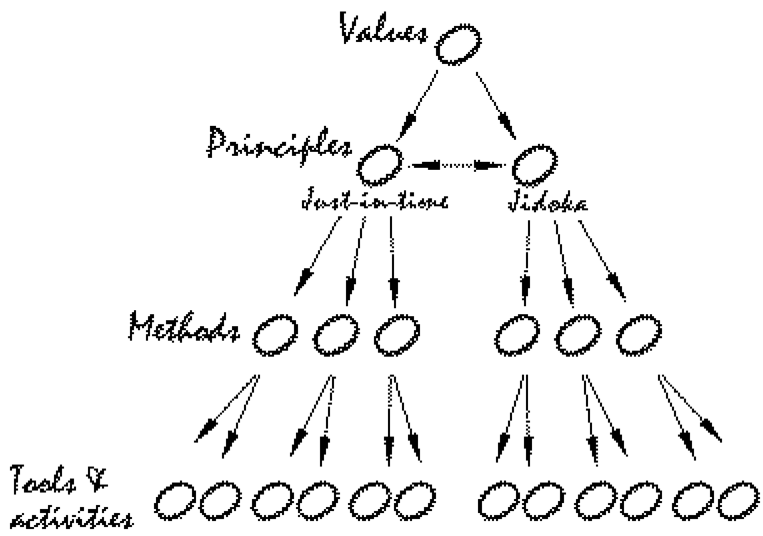
Later, more and more articles pertaining to Lean have adopted respecting of people and management as a strong part of Lean. Taiihci Ohno introduced many different tools that can be used inside the TPS house (Picture 3), but the heart of TPS house is people.



Picture 3. TPS house (Toyota Material Handling, 2010)

Most companies fail while trying to implement Lean to their own business. Tools and practices are fairly easy to implement but if employee engagement is missing, there cannot be true Lean.

The other way to look at the TPS house is to break up the house to a similar shape with Modig & Åhlström in their book. This visualization shows the four layers inside the TPS house. On the top of this pyramid lay the values which describe how an organization should behave. Then, to support values come principles which define how organization should think. Thirdly, methods which define what an organization should do and last, tools and activities which define what an organization should have are implemented.



Picture 4. A different approach to the TPS house (Modig & Åhlström, 2014)

The Toyota Way 2001 (Picture 5) describes employee engagement and the importance of people more clearly. Continuous improvement can only exist only if ideas behind Challenging, Kaizen and Genchi Genbutsu will be adopted. (Toyota Material Handling, 2010.)

An example of challenging current ways of working can be taken from Toyota. During the 2010 tsunami in Japan, Toyota lost 500 subcontractors and faced serious shortage of parts. For most companies this would have been a catastrophic situation but Toyota took the situation as a challenge and an excellent opportunity to improve their ways of working. (Liker & Convis, 2012.)

We believe Lean is all about respecting people while eliminating the 3 M's which are muri (overburdening), mura (unevenness), and muda (non value added activity). Sadly, respecting people is often left out which turns Lean manufacturing into mean manufacturing. (Pereira, 2009.)
Eliminating waste is in the heart of Lean thinking. Most of the Lean implementation projects focus on removing muda. If two remaining M's are forgotten, it can be crucial to Lean implementation. It is important to give enough time to process improvement by redesign.

Jim Womack assumed that by removing waste, overburden and unevenness would also be banished. What he found out by visiting several companies was that many finance and sales departments were busiest at each end of the month. All data, including orders, were processed at the end of the month, resulting a high workload to manufacturing. The inevitable result was that mura created muri that undercut previous efforts to eliminate muda. In short, mura and muri were now the root causes of muda in many organizations. In worse cases the same muda was put back, that managers and operations teams have already eliminated once. (Womack J., 2006.)

What is common when talking about lean in most cases is:

1. The idea of value; for what customer is willing to pay for
2. Eliminate waste; eliminate all non-value creating steps
3. Create flow; any interruptions to the flow have to be made visible
4. Teach people how to think; repeat principles, methods and tools
5. Learn how to improve; focus on why something didn’t work!

2.2 Unevenness (Mura)

Mura equals to unevenness in an operation. For example, a gyrating schedule not caused by end-consumer demand but rather by the production system, or an uneven work pace in an operation causing operators to hurry and then wait (Lean Enterprise Institute, Inc, 2014). Unevenness causes Work-In-Process to increase and inventory levels to rapidly grow to high levels. Unevenness can be reduced by using product leveling and sequencing.

2.3 Overburden (Muri)

Muri equals to overburdening equipment or operators by requiring them to run at a higher or harder pace with more force and effort for a longer period of time than equipment designs and appropriate workforce management allow (Lean Enterprise Institute, Inc, 2014). Muri can be avoided through standardized work. To achieve this, a standard condition or output must be defined to assure effective judgment of quality.

2.4 The definition of Waste (Muda)

Any activity that consumes resources without creating value for the customer is Waste in the terms of Lean (Lean Enterprise Institute, Inc, 2014). It is important to understand that there are two different waste types. Type one is a kind of waste which cannot be removed immediately. An example of type one waste is the hot dipping process, where customer and safety requirements determine the need to file away of any run-off of zinc. Type two is obviously something that can be eliminated immediately.

Ohno detected seven typical types of waste and lately up to eight more have been added. The seven waste types are easiest to pick up since all of them can be visually detected. These seven categories can be introduced as TIMWOOD. The attitudes and tools of the TPS increase awareness and give whole new perspectives to identifying waste and therefore the unexploited opportunities associated with reducing waste.

The first waste type, the waste of Transportation, comes when material is moved unnecessarily. Transportation needs to add value, or it needs to be something that cannot be avoided. In this case, the transportation distance can be reduced.
The need to move things around in order to find space for other things, for example, is often a result of overproduction. Transportation processes involving non value adding steps also are even more wasteful. (Morgan & Brenig-Jones, 2012.)

The second waste type, the waste of Inventories, be it in the form of raw materials, work-in-progress (WIP), or finished goods, represents a capital outlay that has not yet produced an income either by the producer or for the consumer. Any of these three items not being actively processed to add value is waste.

The third waste type, the waste of Motion, refers to the damage that the production process inflicts on the entity that creates the product, either over time (wear and tear for equipment and repetitive strain injuries for workers) or during discrete events (accidents that damage equipment and/or injure workers). The Waste of Motion is usually created in work cells which have not been planned correctly. Inadequate planning lead to unnecessary motion when tool or any other object which is not placed correctly inside work cell.

The fourth waste type, the waste of Waiting occurs whenever goods are not in transport or being processed. In traditional processes, a large part of the life of an individual product is spent waiting to go through the next process phase.

The fifth waste type, the waste of Over-processing occurs any time more work is put on a piece than is required by the customer. This also includes using components that are more precise, complex, higher quality or expensive than absolutely required.

The sixth waste type, the waste of Overproduction is the worst type of waste and it occurs in manufacturing, distribution, or an office, when more than is needed is produced or bought. It is also overproduction when items are made or bought before they are actually needed. Overproduction creates the waste of excess inventories which are very expensive to store, move, count, correct … and the list goes on. The Lean method to eliminate overproduction and to reduce inventories is to implement a concept known as supply chain velocity. (Martichenko, 2012.)

The seventh waste type, the waste of Defects, occurs when something has gone wrong and a product does not meet the customer requirement. Whenever defects occur, extra costs are incurred reworking the part, rescheduling production, etc. This results in labor costs and more time in the "Work-in-progress". Defects in practice can sometimes double the cost of one single product. This should not be passed on to the consumer and should be taken as a loss.

Last, but not least, the eighth type of waste (muda) that will add one point of view to the haunt of waste. As Taiichi Ohno (1976) have stated *“I don’t know who came up with it but people often talk about “the seven types of waste.”* His attention was not to limit the number of different waste types to seven. *“So don’t bother thinking about “what type of waste is this?” Just get on with it and do kaizen”.*

The waste of Skills misuse occurs when organizations employ their staff for specific skills that they may have. These employees have other skills, too, and it is wasteful to not take advantage of these skills as well. It is only by capitalizing on employees’ creativity that organizations can eliminate the other seven types of waste and continuously improve their performance.

3 LEAN INDUSTRY ENVIRONMENT

Toyota motor company has been considered to be “The” Lean Company so in this chapter it is stated how Toyota uses Lean to gain outstanding results and continuous improvement.

Toyota Motor Corporation has used top level business principles from the same precepts from October 30, 1935 . The Toyota Precepts are:

1. Be contributive to the development and welfare of the country by working together, regardless of position, in faithfully fulfilling your duties
2. Be ahead of the times through endless creativity, inquisitiveness and pursuit of improvement
3. Be practical and avoid frivolity

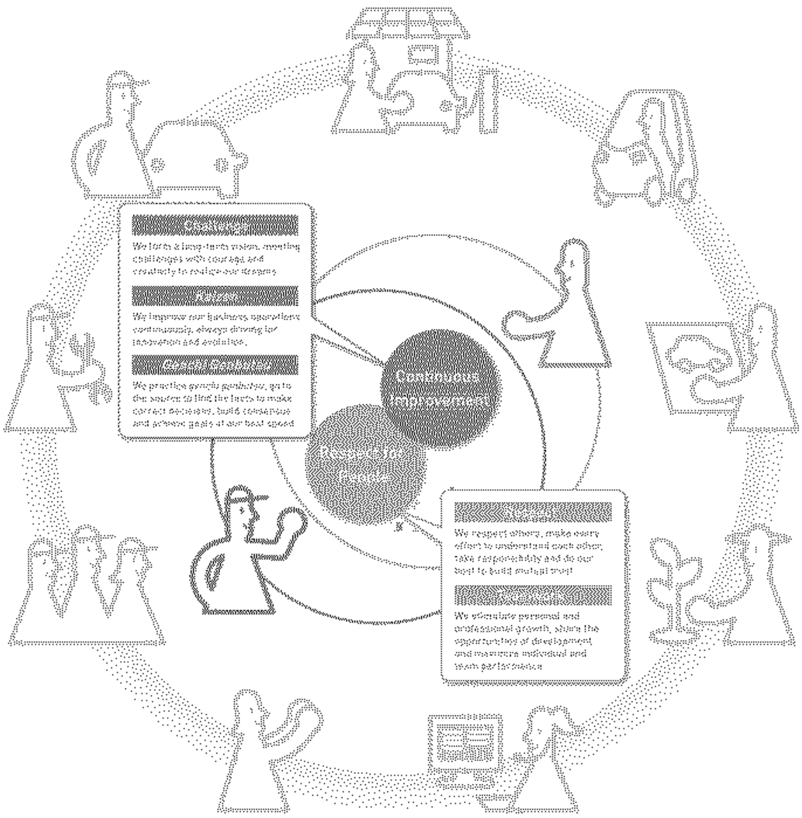
4. Be kind and generous; strive to create a warm, homelike atmosphere
5. Be reverent, and show gratitude for things great and small in thought and deed. (Toyota Motor Company, 2003)

These Precepts are still passed, as a spiritual support, onto the next generations to come as they are still valid for almost every organization.

The following Toyota approach to Lean is divided into parts according to Picture 4 by Modig and Åhlström (2014).

3.1 Corporate Values

Trust, responsibility and teamwork are the key elements for Respect for People. Teamwork, personal and professional growth especially are something that Toyota keeps in high value. According to Liker & Convis (2012) the main purpose of Toyota managers is to seek out new talents and share opportunities of development for them. Most of new managers at Toyota come in-house and it can take many years to become a manager when it is necessary to go through all organizational levels.



Picture 5, the Toyota Way 2001 (Toyota Material Handling, 2010)

3.2 Principles

Principles are needed to support the corporate values. Toyota uses two business principles: Just in Time and Jidoka. Just in Time production strategy is all about creating flow when Jidoka is all about making everything visible. (Modig & Åhlström, 2014.)

Just in Time and Jidoka have been described in many alternative ways from which the two following are good examples.

Just in time (JIT) is a production strategy that strives to improve the return of a business investment by reducing in-process inventory and associated carrying costs. To meet JIT objectives, the process relies on signals or Kanban between different points, which are involved in the process. That indicate the production when to make the next part. JIT focuses on continuous improvement and can improve the return of a manufacturing organization's return on investment, quality, and efficiency. To achieve continuous improvement, the key areas of focus could be flow, employee involvement and quality. (Toyota Material Handling, 2010.)

Jidoka aims to provide machines and operators the ability to detect an abnormal condition and immediately stop work. This enables operations to build in quality at each process and to separate men and machines for more efficient work. Jidoka highlights the causes of problems because work stops immediately when a problem first occurs. This leads to improvements in the processes that build in quality by eliminating the root causes of defects.
Jidoka is sometimes called autonomation, meaning automation with human intelligence. This is because it gives equipment the ability to distinguish good parts from bad autonomously, without being monitored by an operator. This eliminates the need for operators to continuously watch machines and in turn leads to large productivity gains because one operator can handle several machines, often termed multiprocess handling. (Lean Enterprise Institute, 2014.)

3.3 Methods

Methods are everyday actions that support principles. According to Ohno and Modig, Standardization of work is the most important method since it is a method that is used to developing other methods (Modig & Åhlström, 2014). The following pages introduce twelve different methods that are considered common for Lean.

Production leveling (Heijunka) means creation of a level schedule by sequencing orders in a repetitive pattern and smoothing the day-to-day variations in total orders to correspond to longer-term demand (Womack & Jones, 2003). Leveling involves smoothing the volume of production in order to reduce variation. Amongst other things, this technique seeks to prevent the end of period peaks, where the production is generally slow, but then it quickens in the last days of the sales or accounting period, for example. (Morgan & Brenig-Jones, 2012.)

Genchi Genbutsu, or Gemba is a Japanese word meaning the place where work takes place. It is important to see how work is actually carried out since there can be significant deviation between actual doing and how something was planned to be done. It must be understood what needs to be improved and for that purpose a Gemba walk can be a true eye opener. By going to the actual workplace you can pick up first hand information on how things are at the shop floor.

“The gemba and the gembutsu have the information. We must listen to them.” (Ohno, 1976)

Continuous improvement is based on the idea that all processes can be improved, even the one that is thought to be the best in class. Lean terminology use the term Kaizen for continuous improvement. There are two types of Kaizen, Point Kaizen and system Kaizen. System Kaizen will eventually lead to point Kaizen. Value stream mapping can work as an example of system Kaizen. When manufacturing process is improved, improvement process is System Kaizen. If single work cell inside this manufacturing process is improved, it can be called Point Kaizen

Standard work; Standardized work at Toyota is a framework for kaizen improvements. Ohno (1976) describe standard work as follows: “We start by adopting some kind— any kind— of work standards for a job. Then we tackle one improvement after another, trial and error”. This first definition is really common sense and later Martichenko (2012) has discussed the same subject almost like Ohno. Standardization and standard work are critical to continuous improvement because standards provide the baseline against which we judge the impact of change. Without standards, we have no basis for evaluating whether process changes are true improvements.

Lean lexicon explains this subject in a much deeper way which might be also somewhat misleading compared to original idea.

Standardized work means that precise procedures are in place and establishing precise procedures for each operator’s work in a production process, based on three elements:

1. Takt time, which is the rate at which products must be made in a process to meet customer demand.
2. The precise work sequence in which an operator performs tasks within Takt time.
3. The standard inventory, including units in machines, required to keep the process operating smoothly. (Lean Lexicon, 2014.)

“Where there is no standard, there can be no kaizen.” (Ohno, 1976)

5S, or Five S is a systematic way to re-organize workstations. This tool removes waste like lead times by eliminating wasteful activities such as locating the right tool and the movement needed to retrieve it; simplification of assembly procedures in order to reduce setup times; increasing the workplace safety by eliminating risks of accidents. (Rymaszewska, 2012.)

The term 5S or Five S derives from the words Sort, Straighten, Scrub, Systemize and, finally, Standardize:

- Sort encourages you to look at the tools, materials, equipment and information you need to do your job, and separate them into those used frequently, occasionally, and never. You can sort based on your experience, but tagging the items in some way can be (Morgan & Brenig-Jones, 2012.)
-

- Straighten literally means straightening things up and putting everything you use frequently easily to hand. Straightening may include, for example, toolkits, files of email folders, or may involve moving a printer to a more convenient location. Things that you don't use frequently need to be put somewhere else, recycled, or thrown away. You need to decide how many items need storing, how they should be stored and where. Naturally, these stored items should be appropriately labeled to facilitate their easy access in the future. (Morgan & Brenig-Jones, 2012.)

- Scrub concerns keeping the things you use, and the environment you work in, clean and tidy, and appropriately maintained. Make your workplace shine: get rid of rubbish and dirt, and don't leave scarp lying around. Make sure your tools are current, safe and clean, and that all the information and documents you use are up-to-date and well-presented. Check that equipment and machinery are routinely serviced and maintained. (Lean Six Sigma for dummies, 2012.)

- Systemize means straightening your approach. Design a simple way of working so that your tools and information stay sorted, straightened and scrubbed. Essentially, systemize involves regularly re-doing the first three Ss. Doing so helps identify the reasons why the workplace becomes messy and cluttered, and prompts preventive thinking to find ways of stopping the problems recurring. (Morgan & Brenig-Jones, 2012.)

- Standardize the whole approach and keep doing it. Stick to this system every day, train everyone in the application of the Five Ss, regularly review things and tell others about your effective method of working so it becomes a way of life. (Morgan & Brenig-Jones, 2012.)

One piece flow (continuous flow) means producing and moving one item at a time (or a small and consistent batch of items) through a series of processing steps as continuously as possible, with each step making just what is requested by the next step. Continuous flow can be achieved in a number of ways, ranging from moving assembly lines to manual cells. It also is called one-piece flow, single-piece flow, and make one, move one. (Lean Enterprise Institute, 2014.)

Error-Proofing Methods that help operators in their work avoid mistakes caused by choosing the wrong part, leaving out a part, installing a part backwards, etc. Also called mistake-proofing, poka-yoke (error-proofing) and baka-yoke (fool-proofing).
Common examples of error-proofing include:

- Product designs with physical shapes that make it impossible to install parts in any but the correct orientation
- Photocells above the containers of the parts to prevent a product from moving to the next stage if the operator's hand have not broken the light to obtain necessary parts
- A more complex parts monitoring system, again using photocells, but with additional logic to make sure the right combination of parts was selected for the specific product being assembled. (Lean Enterprise Institute, 2014.)

Cellular manufacturing; The location of processing steps for a product immediately adjacent to each other so that parts, documents, etc., can be processed in very nearly continuous flow, either one at a time or in small batch sizes that are maintained through the complete sequence of processing steps. A U-shape (shown on page 8) is common because it minimizes walking distance and allows different combinations of work tasks for operators. This is an important consideration in Lean production because the number of operators in a cell will change with changes in demand. A U-shape also facilitates performance of the first and last steps in the process by the same operator, which is helpful in maintaining the work pace and smooth flow. (Lean Enterprise Institute, 2014.)

Supply Chain Velocity is created by moving smaller quantities of material more frequently with standard, leveled (meaning they are of the same quantity over the available time), and consistent timing. Velocity will reduce the amount of inventory is needed to keep on hand. As the inventory levels are reduced, problems that have been hidden by the inventory will begin to be exposed. And as learned, exposing problems is good. (Martichenko, 2012.)

The mechanisms for achieving supply chain velocity are improving flow and moving to a pull-replenishment system.

Total Productive Maintenance (TPM); A team-based system for improving Overall Equipment Effectiveness (OEE), which includes availability, performance, and quality. This aids in establishing a strategy for creating employee ownership autonomously for maintenance of equipment. The goal of the TPM program is to markedly increase production while at the same time increasing employee morale and job satisfaction.

Firstly, it requires a total participation of all employees, not only maintenance personnel but line managers, manufacturing engineers, quality experts and operators.
Secondly, it seeks total productivity of equipment by focusing on all of the six major losses that plague equipment: downtime, changeover time, minor stops, speed losses, scrap, and rework.
Thirdly, it addresses the total life cycle of equipment to revise maintenance practices, activities, and improvements in relation to where equipment is in its life cycle.(Lean Lexicon, 2014.)

OEE (Overall Equipment Efficiency) :
OEE = A x PE x Q
A = Availability of the machine.
PE = Performance Efficiency
Q = Refers to quality rate.

SMED is a process for changing over production equipment from one part number to another in as little time as possible. SMED refers to the target of reducing changeover times to a single digit, or less than 10 minutes. Shigeo Shingo’s key insights about setup reduction, which were developed in the

1950s and 1960s, were separating internal setup operations— which can be done only when a machine is stopped (such as inserting a new die)— from external operations that can be performed while the machine is running (such as transporting the new die to the machine), and then converting internal setup operations to external operations. (Lean Enterprise Institute, 2014.)

3.4 Tools and activities

Tools and activities is something that can immediately be seen at the shop floor. Tools and activities are how methods are realized. A method is built up of activities (what we do) and tools (what we have). (Modig & Åhlström, 2014.)

Takt time is the rate of customer demand for the group, of family, of products produced by one process. Takt time is calculated by dividing the effective operating time of a process by the quantity of items customers require from the process in that time period. Effective operating time is the available time minus planned maintenance. Unplanned downtimes and changeovers times are not subtracted at this point, because they are variables you want to reduce. (Toyota KATA, 2010.)

$$\text{Takt time} = \frac{\text{The effective operating time per shift}}{\text{Quantity customer requires per shift}}$$

Figure 1. Takt time calculation

Process stamping is one of the basic tools to start any improvement action. According to Morgan and Brenig-Jones (2012) with process stamping you begin to understand all the steps in the process and how much time and movement is involved in carrying out the work. Process stamping helps you indentify a number of improvement opportunities meaning that waste of waiting, transportation and motion can be reduced.

Process stamping means taking a customer order and walking it through the entire process, step by step, as you were the order. It is important that this activity is done at Gemba, not in a meeting room. Process stamping differs from Value Stream Mapping (see 4.3) in the way that it will go deeper into the process step.

A spaghetti diagram provides a picture of what happes in the process in terms of movement (Morgan & Brenig-Jones, 2012). This tool can be applied to the entire process or just one task inside a process and it provides a visual catalyst to stimulate change in the workplace. Any cad solution can be very helpful for this purpose because a diagram can be drawn and have the system measure how far people move. Usually, you can use a digital layout of a process but it is fairly simple to draw up a sketch of layout. Once the layout is ready, the movement of people as they proceed with their work is recorded (by drawing it by using pencil, cad, etc).

Value Stream Mapping has been described in many books to be the most effective tool to identify the process at top level. According to Lean lexicon (2014) it is a simple diagram of each step involved in the material and information flow needed to bring a product from an order to delivery. Rother (2010) adds the concept of lead time to VSM.

Value-stream maps can be drawn for different points in time as a way to raise consciousness of opportunities for improvement. (Lean Enterprise Institute, 2014.)

Value Stream Mapping starts from a current-state or an as-is map which follows the path of the product from order to delivery to determine the current conditions.

A future-state or to-be map deploys the opportunities for improvement identified in the current-state map to achieve a higher level of performance at a future point. Reducing waste elements can be found too expensive or to require significant amount of recourses. This is usually where finance is involved to turn a Lean case in to an investment case.

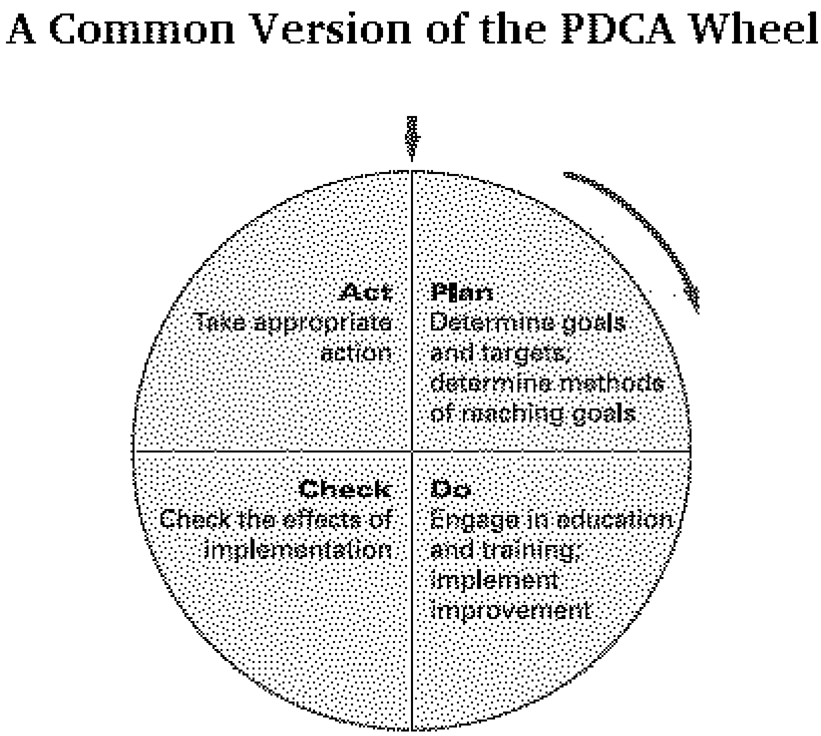
In these cases, it may be appropriate to draw an ideal-state map showing the opportunities for improvement by employing all known Lean methods including right-sized tools and value-stream compression. (Lean Lexicon, 2014.)

The Five why is the practice of repeatedly asking why whenever a problem is encountered in order to get beyond the obvious symptoms to discover the root cause. The following example about a machine that stopped working was given by Ohno(1976):

1. Why did the machine stop? There was an overload and the fuse blew.
2. Why was there an overload? The bearing was not sufficiently lubricated.
1. Why was it not lubricated? The lubrication pump was not pumping sufficiently.
2. Why was it not pumping sufficiently? The shaft of the pump was worn and rattling.
3. Why was the shaft worn out? There was no strainer attached and metal scraps got in.

Without repeatedly asking why, managers would simply replace the fuse or pump and the failure would recur. The specific number five is not the point. Rather it is to keep asking until the root cause is reached and eliminated. (Lean Enterprise Institute, 2014.)

PDCA or an improvement is a cycle based on the scientific method of proposing a change in a process, implementing the change, measuring the results, and taking appropriate action. It also is known as the Deming Cycle or Deming Wheel after W. Edwards Deming, who introduced the concept in Japan in the 1950s. The PDCA cycle has four stages: Plan: Determine goals for a process and needed changes to achieve them. Do: Implement the changes. Check: Evaluate the results in terms of performance. Act: Standardize and stabilize the change or begin the cycle again, depending on the results. (Lean Enterprise Institute, 2014.)



Picture 6, Deming’s PDCA wheel.

A Kanban is a signaling device that gives authorization and instructions for the production or withdrawal (conveyance) of items in a pull system. The term is Japanese for “sign” or “signboard.” Kanban cards are the best-known and most common example of these signals. They are often slips of a card stock, sometimes protected in clear vinyl envelopes, stating information such as part name, part number, external supplier or internal supplying process, pack-out quantity, storage address, and consuming process address. A bar code may be printed on the card for tracking or automatic invoicing. Besides cards, Kanban can be triangular metal plates, colored balls, electronic signals, or any other device that can convey the needed information while preventing the introduction of erroneous instructions. Whatever the form, Kanban has two functions in a production operation: It instructs processes to make products and it instructs material handlers to move products. The former use is called production Kanban (or make Kanban); the latter use is termed withdrawal Kanban (or move Kanban). (Lean Enterprise Institute, 2014.)

After all these principles, methods and tools Womack and Jones exceptionally pointed out that despite 5 S, 5 why's, 7 forms of waste, the exact numbers are not important. More important is to understand the idea how to eliminate waste and create value by using a systematic approach and endless attention to details.

4 LEAN THINKING

This chapter aims to answer the question of how to start the Lean journey by using Womack's (2003) example where Lean Thinking starts from value determination and ends up in striving towards perfectionism.

4.1 Customer Value

First, it is important to pay attention to the term value. If a company doesn't create value to its customers, it is hard to imagine any long-term prosperity. Value can be determined to be something that a customer is willing to pay for.

Value is defined as the level of effect that people personally expect from products and services, represented through lifestyle impact, enabling features, and ergonomics, which together result in a useful, usable, and desirable product. (Cagan & Craig, 2002.)

The customer defines the value despite the fact that the customer might not see how value is created (Lean Enterprise Institute, Inc, 2014). This means that producers need to know how value is created to the customer and that creates some challenges.

Customers can (and they usually do) also change their opinion about the value. This means that value should be considered from time to time and rethought together with the entire supply chain/Lean enterprise. (Lean

Enterprise Institute, Inc, 2014). Value is not a permanent term so customers and market trends should always be listened to closely. But when to react, depends on the company ability to make a change.

The Lean enterprise focuses on adding value to the customer. Any activities that do not add value are considered waste. The sequence of activities that add value comprise what is called the value stream—the flow of the important parts of the process that create the products and services for the customer. (Martichenko, 2012.)

4.2 The Value Stream

All work is a process and usually a process includes People, Equipment, Method, Material and Environment. When all processes which are needed to create a product to the customer are sequenced the Value stream is created. A value stream can be misleading since this stream also includes waste elements which don’t add any value.

All the actions required to bring a product from concept to launch (also known as the development value stream) and from order to delivery (also known as the operational value stream) can be divided into value creating (VA) and non value creating (NVA) actions. (Lean Enterprise Institute, 2014.)

Lean enterprises put a lot of effort into defining, studying, and improving their value streams. It helps to know what needs to be eliminated or improved by separating all your processes or activities into three categories (Martichenko, 2012). The three categories that Martichenko describes are Value adding, Non value adding and Business Value Adding activity.

Value Adding (VA): This activity is the one that the customer is willing to pay for.

Non Value Adding (NVA): This activity is waste and it needs to be eliminated. Customers are not willing to pay for this

Business Value Adding (BVA) or Necessary Non Value Adding (NNVA) activity is any activity or process the customer would not want to pay for, but which cannot be eliminated at this point. These processes need to be rationalized, then minimized, and automated where possible.

4.3 Flow

“Let the flow manage the processes, and not let management manage the flow.” (Ohno, 1976)

The earliest definition of flow comes from automobile industry and it can be described as follows: The objective of flow production is to drastically reduce product throughput time and human effort through a series of innovations. These include consistently interchangeable parts so that cycle time can be stable for every job along an extended line, the line itself, the reconfiguration of part fabrication tasks so that machines are lined up in process sequence with parts flowing quickly and smoothly from machine to machine, and a production control system insuring that the production rate in parts fabrication match the consumption rate of parts in final assembly. (Lean Enterprise Institute, 2014.)

Lean introduces one-piece-flow and from that time on flow has been seen as follows: Producing and moving one item at a time (or a small and consistent batch of items) through a series of processing steps as continuously as possible, with each step making just what is requested by the next step. Continuous flow can be achieved in a number of ways, ranging from moving assembly lines to moving manual cells. It is also called one-piece flow, single-piece flow, and make one, move one.

4.4 Pull

Pull is a method of production control in which downstream activities signal their needs to upstream activities. Pull production strives to eliminate over-production and is one of the three major components of a complete just-in-time production system. Operation, either within the same facility or in a separate facility, provides information to the upstream operation, often through a Kanban card, on what part or material is needed, the quantity needed, and when and where it is needed. Nothing is produced by the upstream supplier process until the downstream customer process signals a need. This is the opposite of push production. (Lean Enterprise Institute, 2014.)

4.5 Perfection

According to Womack (2003), complete elimination of muda is possible. By having this in mind, competition with others will have less meaning since the main focus will be in improving own processes. Strive to perfection needs solid understanding of previous four phases: Value, Value stream, flow and pull. Perfection can be reached in two ways, by continuous radical or incremental improvement but it is important to determine which forms of waste to attack first.

Womack (2006) alters his previous at the year 2003 created Lean thinking path. He points out three main elements; Purpose, Process and People.

Purpose: The primary purpose of any organization and first step in any Lean thought process is to correctly specify the value that the customer seeks in order to cost-effectively solve the customer’s problems so the organization can prosper.

Process: Once purpose is clarified, focus on the process (value stream) will be used to achieve this objective. This is generally the combined result of three processes: product and process development, fulfillment from order to delivery, and support of the product and the customer through the useful life of the product. These primary processes are made possible by many secondary support processes inside the organization and upstream. The ideal process is one in which every step (action) is:

- Valuable: Meaning that the customer is willing to pay for the step because it creates value and would object if the step was deleted.
- Capable: Producing a good result every time.
- Available: Being able to operate whenever needed.
- Adequate: Having the capacity to keep production in continuous flow.
- Flexible: Permitting a range of products within a product family to move through a process without batching and delays.

In addition, in the ideal process the steps are linked by:

- Flow: So the good or service proceeds immediately from one step to the next without stopping.
- Pull: So the next downstream step obtains just what it needs from the next upstream step when continuous flow is not possible.
- Leveling: From some pacemaker point to smooth the operation of the process while still addressing the needs of the customer.

People: After identifying the primary and support processes needed to create value for the customer, someone has to be made responsible for each value stream. This value-stream manager must engage and align the efforts of everyone touching each value stream to move it steadily toward the customer while elevating performance from its current state to an ever-better future state. Doing this requires:

- A master plan for the enterprise, often called strategy deployment.
- Frequent improvement cycles for each process, often performed with A3 analysis embodying value-stream maps.
- Standard work with standard management for every step in each process.

5 RESEARCH IMPLEMENTATION

Corporate and case company information is given at the beginning of this study to give a brief understanding of the background. Also, implementation steps are discussed here in detail to show how the results have been reached. The implementation schedule is described in picture 11 and all the steps that are discussed in this part are not in chronological order. Instead the task-based order has been used

5.1 Outotec Oyj

Outotec is a global leader in minerals and metals processing technology, Outotec has developed many breakthrough technologies over the decades. The company also provides innovative solutions for industrial water treatment, the utilization of alternative energy sources and the chemical industry.

The strong market position and technology leadership of Outotec are based on the knowledge and experience derived from the operations of two major mining and metals companies: on the know-how based on historic position of the company as a part of the Outokumpu Group, particularly when mining and metallurgy formed a key part of the operations of the Outokumpu Group and it spent substantial resources on creating related technologies, as well as on the know-how of former Lurgi Metallurgie GmbH, originating from Metallgesellschaft AG.

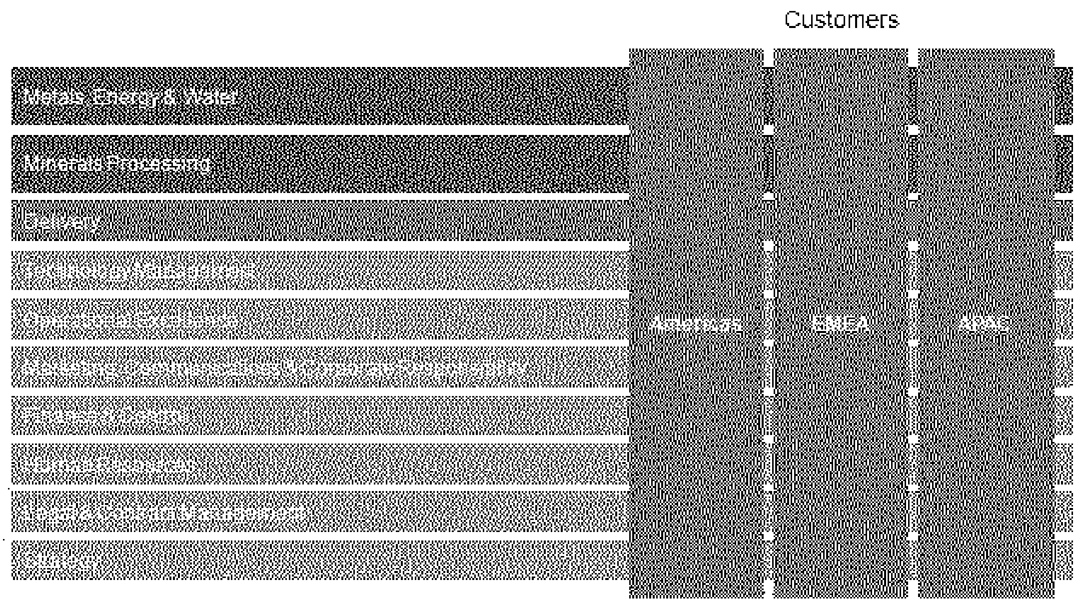
Outotec Oyj Sustainability is at the core of what Outotec does. This means helping our customers create the smartest value from natural resources and working with them to find the most sustainable solutions for water, energy, minerals, and handling the full value chain from ore to metals.

Sustainable use of natural resources of the Earth is one of key messages that Outotec highlights everywhere.
We provide our customers with technology solutions and services that support the entire life cycles of processes, including their operation and mainten-

ance. Our offering is based on decades of technology leadership and commitment to developing sustainable solutions.

We tailor solutions to our customers' needs. This ensures that they receive the smartest value from virtually all types of ore while making the least impact on the environment. In addition, our global sales and service network guarantees that there is always an experienced Outotec professional on hand for support.

Outotec sales and service centers in 27 countries and six continents ensure integrated operations, yet close proximity to our customers. Our operations are clustered into three regions: the Americas, EMEA (Europe, the Middle East and Africa), and APAC (Asia Pacific), providing our customers with full support for project implementation, deliveries and service.



Picture 7, Outotec operating model (Outotec, Outotec Strategy, 2014)

The two business areas (picture 2): Minerals Processing, and Metals, Energy & Water are dedicated to developing sustainable technology solutions and life cycle services.

MINERALS PROCESSING	METALS, ENERGY & WATER
Concentrators	Non-ferrous metals
Comminution	Ferrous metals and ferroalloys
Flotation	Light metals
Dewatering	Industrial water treatment
Services	Services
Operation & maintenance	Operation & maintenance

Picture 8, Outotec business areas

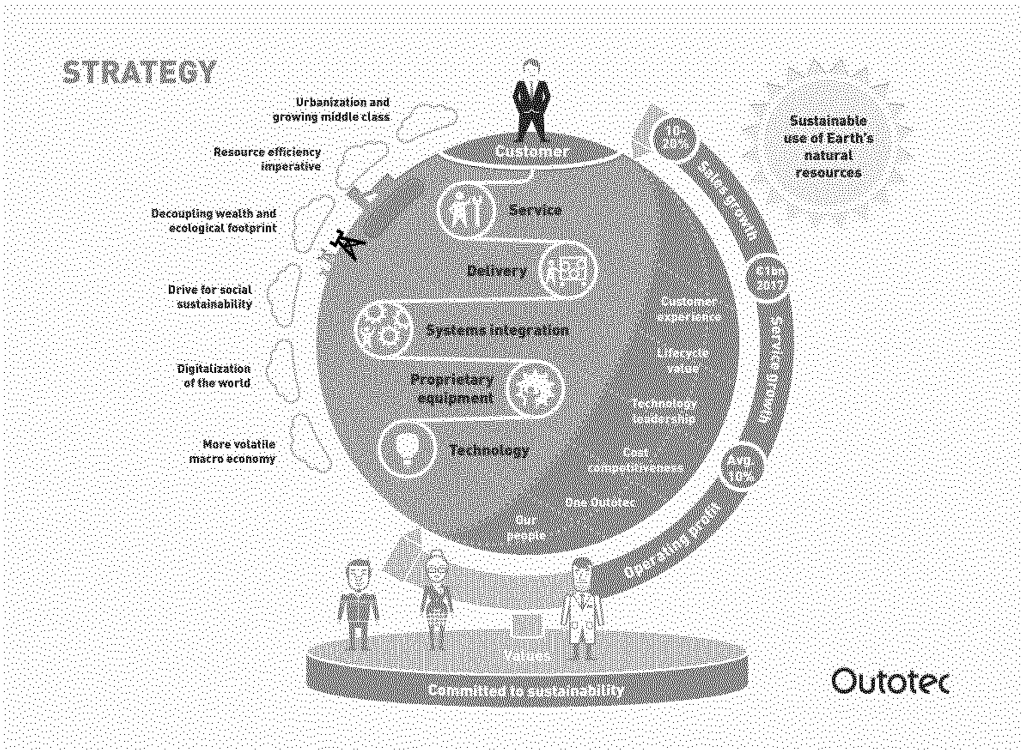
5.1.1 Outotec values

In the heart of Outotec values is strong commitment to sustainability. The three supporting values bring people into this picture. *We build success together* means that there should be one Outotec thinking instead of BA's or business lines and also to that success is build together with clients, *we aspire for excellence* in Lean terms means that there is always room for improvement and *we create leading technologies for our customers* means that leading technologies are created with strong focus on sustainability and future generations.

Picture 9, Outotec values (Outotec, Outotec Values, 2014)

5.1.2 Outotec strategy

The goal of Outotec is continuous profitable growth. The strategy of Outotec is based on the company's mission 'Sustainable use of Earth's natural resources', competent people and values. With the core value 'Committed to sustainability' Outotec builds success together, aspire for excellence and create leading technologies for customers.



Picture 10, Outotec Strategy (Outotec, Outotec Strategy, 2014)

As stated earlier in part 1.2 Outotec (Ceramics) has expanded its manufacturing capacity significantly within the last 5 years. Also the decision that all non-Outotec products were cut off at the same time led to a situation where manufacturing premises were not optimized. It had been agreed earlier that once all machinery that was in place to make non-Outotec products were scrapped, a new layout needed to be designed. This new layout would need to meet the requirements which were set up by two main product categories. The remaining products are would be ceramic filter elements that are used in mining industry. This left the company with a question of how to create a new layout and on what basis?

At the same time, the launch of O'Lean pointed the way to use the VSM study to determine how the process works and how much waste there was.

It was agreed that a full scale VMS study would be made on one product, Black 36 filter element at this point but also a measurement for Blue 24 would be carried out at the same time and analyzed after Black 36. This was mainly due to the fact that at that time, these two were the main elements in production and there was no reason to start unnecessary processes for this purpose only. The VSM approach was decided on because there was a clear need to map out all process steps and to determine how each step was carried out.

5.2 Research start-up

Before any work started it was clear that there was a need to increase knowledge on this subject called Lean. First, a brief introduction was held by Erkki Wirta from a company called Fore and Aft and the introduction was about waste management, how to determine VA, NVA and BVA and throughput time. An interesting point of view of how motivation and, as the Lean philosophy describes, the people, can make the difference was introduced by Wirta.

Power of motivation, 6 persons:

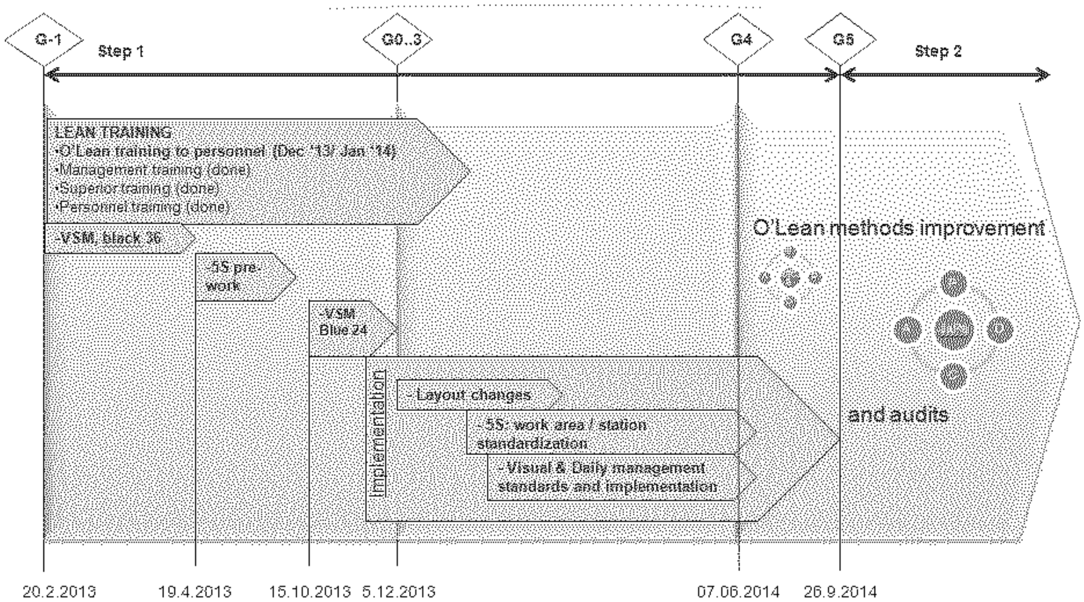
-**"Normal" way of working (level of motivation = 1,0) 1,0x1,0x1,0x1,0x1,0x1,0 = 1,0**

- **People partly against (level of motivation = 0,8) 0,8x0,8x0,8x0,8x0,8x0,8 = 0,26**

- **Enthusiastic people (level of motivation = 1,2) 1,2x1,2x1,2x1,2x1,2x1,2 = 2,99**

Most white collars and two senior production operators took this training but the need to engage all the people became clear after this power of motivation.

The following picture describes the original project phases and the preliminary implementation plan for O'Lean which was created after the first training.



Picture 11, O'Lean project plan

5.3 Lean training

The First training was held at the beginning of 2013 by Matti Torkkeli from Lean5. The trainings were conducted in two days so that the first day was for all staff and the second for the Lean core team. The first day training focused on Lean basics and principles like 7 waste and flow. The training also included a short exercise which demonstrated how to create flow and how flow has affected on production. On the second day, the core team was trained to gain deeper understanding about VSM, how to eliminate 7 waste and most importantly, how to observe the current situation on site. Held the training at this point was chosen on the ground that, immediately after the training, the VSM exercise was started (explained in more detail in 6.1).

The second training was held in late 2013 by Sunprofile Oy and it only was for the core team. At this point, it is important to point out that the core team had changed totally from the previous training. Between January 2013 and

December 2013 the number of employees dropped down dramatically from 47 to 25. Everyone else except one blue collar of the original core team were laid off. This alone was a strong enough reason to take another training event. This two-day training was a hands on training where all participants were taught how to build up pedal cars in the most effective way by using Lean methods like Production Leveling, Takt time, 5S and Standardization of Work Methods.

During 2013, an additional management training focusing on Lean implementation took place at Aalto University. The plant manager participated in a twelve-day course DOM (Diploma in Operations Management) and the Manager of the Plant Services achieved an LSSGB (Lean Six Sigma Green Belt) certification.

The third training was held in January 2014 and it was for all the staff. This 2-day training was about 5S and Production Leveling using Lean methods. During the first day, practical 5S events took place at the factory floor. Three workstations were picked out as examples of how to run first 3S's and what it mean. Improvement tasks were also tested and carried out during this short exercise. A classroom training event was held on the second day by Lean5, Matti Torkkeli. The aim of this training was to freshen up Lean mindset and to remind how Lean will bring results.

5.4 Benchmarking

The first benchmarking took place at Nestle Oy, Turenki plant. The purpose of this benchmarking was to find out on how Nestle has adopted the Lean methods, therefore a benchmarking team was divided into small teams, all having own focus areas. The Nestle Lean journey took place at a point where the Turenki plant was the Lean pilot plant in Finland and Nestle Turku was following it shortly.

The second benchmarking took place at Teleste, Turku. Teleste won the Lean Act award in 2013 for its achievement in making the production flow and therefore an interesting plant to visit. All Outotec (Ceramics) workers took part in this benchmarking so that they would see how Lean works in real manufacturing. Teleste has been focusing on how production flow is established and how management layers can be lowered. Spaghetti diagrams had been used to see how a product moved through all processes and how it could flow more smoothly.

Unofficial benchmarking took place at the counter of Hesburger. When I followed how the cashier took my order, I saw that she looked at the screen behind from time to time. On that screen, all the products that are ready can be seen. There, the cashier can immediately see when my order is ready. This was practical benchmarking of visual management.

5.5 The Mapping of the value steam

The Value stream mapping was carried out using the following structure:

1. Identify the process you want to look at, agreeing the start and stop points
2. Set up a small team to do the analysis
3. Go to The Gemba
4. Working at a reasonable high level, draw a process map of the material/product flow in the whole value system
5. Identify the performance data you'd like to know
6. Collect the data you need for each step in the process
7. Add an overall timeline to show the average cycle time for a item

Step 1. The process that was agreed to be studied was selected as stated earlier in this study. Also, it was decided that information flow was not included because that this VSM study was primarily meant to improve the manufacturing process by means of flow. So the VSM in this study focuses on map out the manufacturing process only. At this point it was also agreed on that the customer, was Outotec as an internal customer.

Step 2. After the decision on which product the VSM was focused on a team was gathered. The team included 4 operators, 2 senior operators, a production manager and a Lean (VSM) Manager. All operators were closely involved in the VSM process and all opinions and suggestions were noted.

At first, this group created a top level VSM map (see pict. 11) as a desk top study by using post-it notes. The orange color would indicate one process step, pink indicated the waiting time like storing, drying, warehousing. By doing this exercise, the whole manufacturing process was visualized and therefore it was much easier to communicate what the VSM was all about for this process.

Picture 11, Top level VSM

Steps 3-7. From this background, the VSM team was divided by process steps to go to gemba and make the necessary observation. A timeline was also given when observation had to be conducted. The VSM team measured the distances an operator needed to go during a workday. Also, they counted the manufactured parts and took time for each part. Additional observation was also conducted at the same time, and this information was also written down to the VSM mapping table (appendix 1). This additional information consisted of the improvement suggestions of the observers and operators, drawings of how a workstation could work better and questions about why something is done in a specific way.

The most important thing was to understand that the main focus was not on following the operators; it was to follow how a product moves along a production process.

In total, 24 workstations were observed and most of them were observed twice to see how much variation there is between the operators. All information was then collected to one meeting room which was reserved for the VSM team for as long as they would need it.

5.6 5S

Before the layout change started, it was necessary to start a 5S implementation.

This was obvious because that this way the need to move unnecessary tools, equipment etc. could be limited or even avoided. It was easy to see that during rather a long company history, many things had just been left around for just in case needs.

As described on page 27 5S has five different stages. Before the layout change the first two, Sort and Straighten was agreed to be implemented and once the layout change was carried out, all five steps would be implemented.

6 RESULTS

6.1 Benchmarking

Case Nestle:

It was extremely important to see how a plant can be managed without sophisticated IT systems. Instead, Nestle uses daily management boards and visual management to keep their operations and processes running.

Case Teleste:

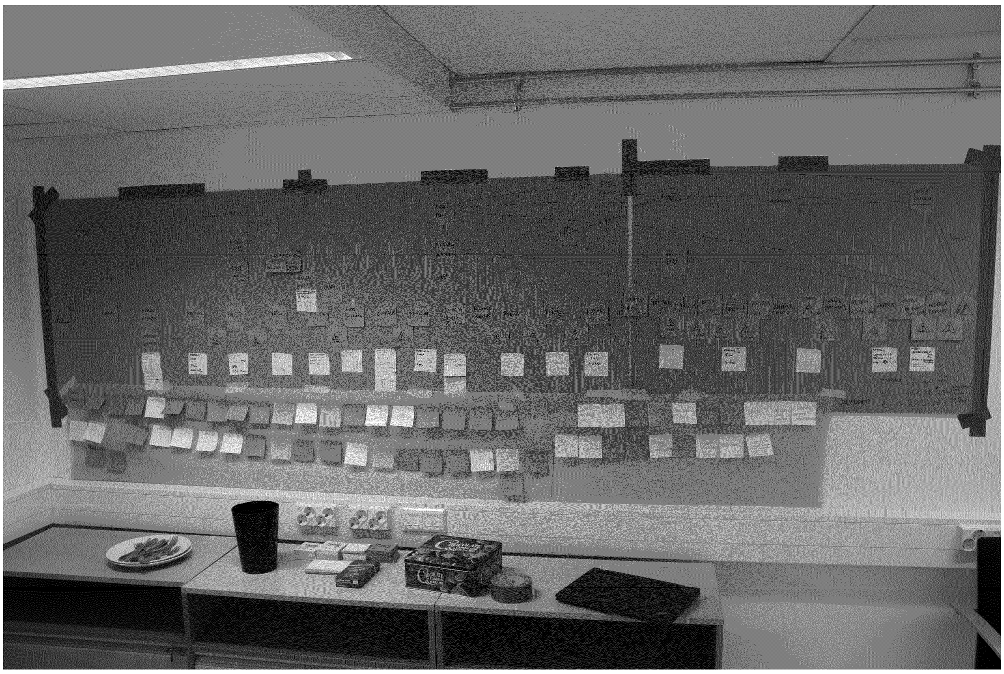
The main takeaways from Teleste were that no major investments were needed to make the production flow or to make major improvements. Also, it was interesting to see that plant management was placed to sit on the shop floor. This way communication is much easier and the management is present most of the time.

Most importantly, it was interesting to see that neither of these companies has adopted 5S. Visual and daily management systems were implemented and VSM studies were also in use. This shows that Lean manufacturing can be implemented in many different ways. When Outotec O'Lean model focus on implement VSM first and secondly the 5S other companies can use a totally different approach. "Where there is no standard, there can be no Kaizen." (Ohno, 1976). In both of the companies that were benchmarked, standardization was implemented in some form. Nestle had daily management practices that were standardized at all levels of their management system.

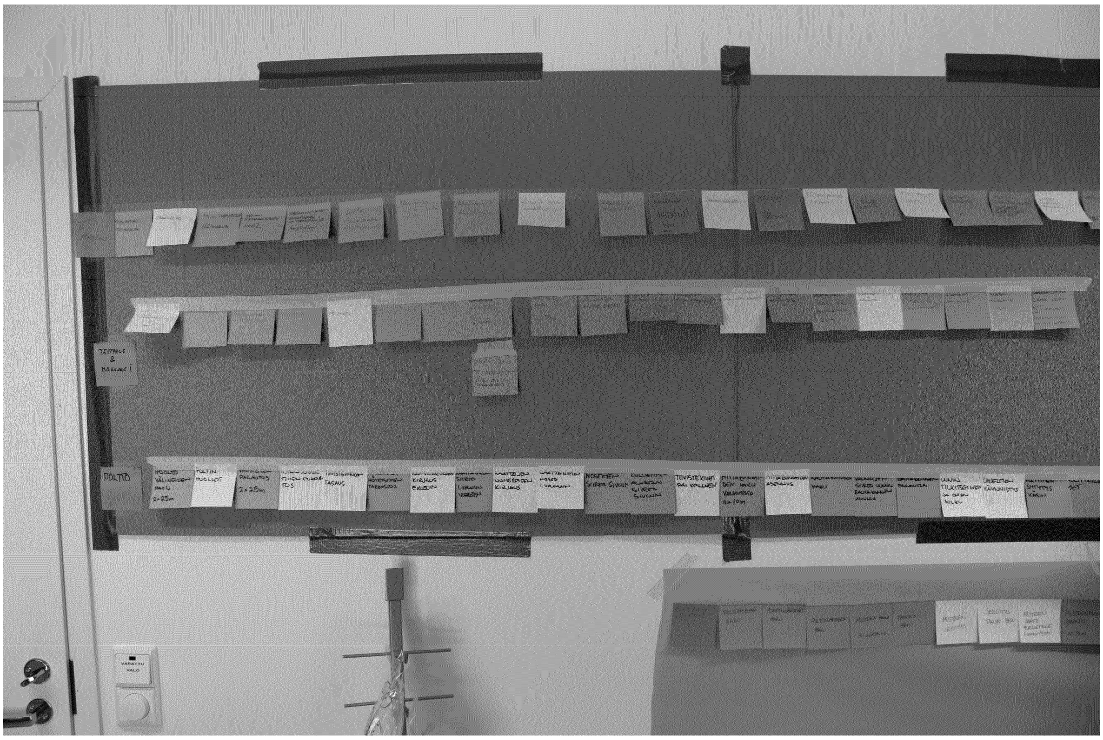
6.2 The Mapping of the value steam

The top level study made earlier was now expanded to three walls so that each process step would be broken down in tasks which needed to be conducted before a product could move to the next workstation. All steps were laid out by using post-it notes again. The post-it note contained information of what happened at a specific point of the production process, the time it took and last it was categorized to be green (Value Adding task), yellow (Non Value Adding, but necessary task) and pink (Non Value Adding task).

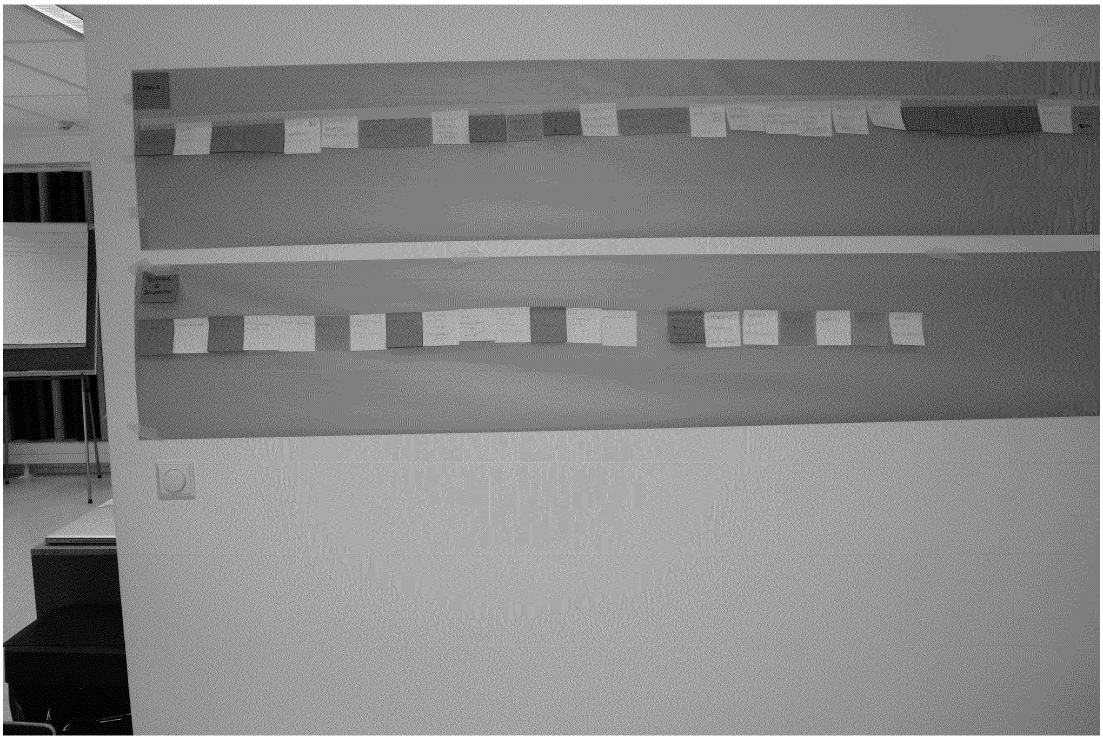
Once all workstations were measured and reviewed, all data was gathered together and based on this data, a current situation map was drawn. (see pict. 12.1-3). All information was gathered on VSM forms (appendix 1) and then moved to the walls by using post it notes. This made the result easier to visualize. The gathered data was also fed into Excel for further processing. Once all process steps were laid out in visual form, this material covered 14m of wall space in two rows. At this point all steps were given a rating by using colors. Green would be a Value Adding task, yellow a BVA and red a NVA. On top of that, the throughput time and capacity of all steps were written out on these walls. At this point, the current state of manufacturing process could be visualized as it was at the time it was measured. The first and the most obvious finding was that the current state processes were not following SOP's (Standard Operating Process) and also that all SOP's needed to be reviewed.



Picture 12.1, All VSM steps



Picture 12.2, All VSM steps



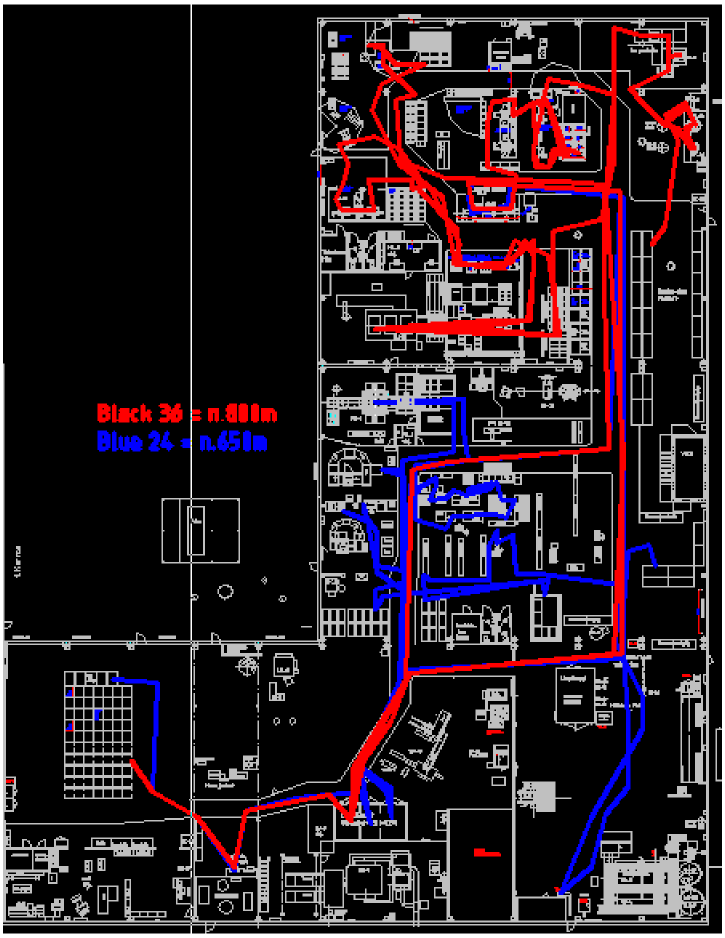
Picture 12.3, All VSM steps

This current state VSM study was introduced to all employees and the meeting room was open for comments for one week. The observers explained what they had done and in case there was something that needed to be discussed they did it. This was just to make sure that everyone could understand what VSM was all about and also to discover if some process steps were not included.

All additional information that was received at this point was written down on a flap board. This hidden knowledge and information is extremely important to understand because it can prevent major mistakes when making future steps. An example of hidden information, an operator has done some process step another way that he normally does it and the observer has not been able to point this out. During the introduction of VSM study all participants were asked to go thru once again the production process step by step so that they were able to tell if something was not “as it should be”. In this case, hidden information, as it is retrieved, has two advantages. First, correct information would make the overall outcome more realistic and reliable and secondly, the reason behind any deviation can be discussed and determined to avoid such of thing happen again.

Also, a spaghetti diagram was drawn (Pict. 13) out of the two main products. It indicated that for the Blue 24(blue line), it takes 640 meters for one product to go through the production process and for the Black 36 (red line) 800 meters.

This spaghetti diagram is a true eye-opener as it shows clearly how one product actually moves and without this diagram it is difficult to see the movement from the factory floor. This indicated the importance of a new layout.
Several situations where production flow was crossing were identified. The production was not flowing, drying chambers were located far away, the layout was tight and there weren’t proper markings for workstations or forklift truck ways etc.



Picture 13, Spaghetti diagram

At this point, it became obvious that it wasn’t that easy to categorize all process steps. Steps that add value were easy to point out but NVA and BVA steps were much more difficult to determine. This is not so important since both NVA and BVA are waste and need to be considered to be removed or reduced. For an example, the drying time that is needed for one piece is 13 days and one hour. These drying steps come after testing, painting and coating of the product and all these were considered as BVA. All these can be reduced; However, removing these totally would require costly investments like paining line. Some reduction could be achieved by changing the paint type, but that requires a lot of testing since the condition where these products will end up are hostile.

Based on the current status VSM data the throughput time for one Black 36 was 71 days. This information was compared to the actual throughput time and it was quite accurate. Normally, it took 3 months for one Black 36 to go through all process steps.

6.3 The future and the realistic state

A future state process was created by the VSM ream members. There was no limitation at the beginning because all ideas were welcome and all ideas were just as good as any. The point was that everyone could bring even the craziest idea on the table. The target was reached and a lot of ideas came in. One of them was to use a new method in drying ceramic elements and maybe even use this method instead of firing the ceramic elements. Secondly, this exercise increased the awareness of one piece flow.
Once the future state had been built, it was time to move to the realistic state. The investments that were necessary to create flow were included to the realistic state. Also, relocation and modification of an existing workstation was included.

As a result of this exercise, the throughput time for one plate was improved by 67% by implementing 257 different improvements that were found during the VSM study and all these improvements aimed to reduce the Non Value Adding time. 120 of 257 improvements did not require any investments and these could be implemented immediately. The investments that were estimated to be roughly 65 000€ would bring 81 improvements and what is more important, increase the safety significantly by removing the need to lift products manually. These lifting process steps also require two workers every time so the overall effect is significant.

The share between the Value Adding and Non Value Adding time was 33/66% before any work was carried out. After the VSM this ratio was reduce to 57/43%. This comparison was made so that NVA and BVA were both considered to be Non Value Adding time and the kiln time (firing cycle) was Value Adding time. This explains the high share of Value Adding time in this comparison.

6.4 Process capability

The Process capability increased in several ways. One of the reasons was the implementations of the investment plan which enabled more people to do Value Adding work instead of lifting when helping others to move the product.

A production bottleneck was determined to be the kiln capacity. To increasing the process capability significantly would mean high a investment to in purchase a new kiln. The current situation can be improved by 27% by implementing a new kiln but this kind of investment would require a market change or a new, high volume product, otherwise the pay-pack time would be long. At this point, the idea of a new kiln was left out of consideration.

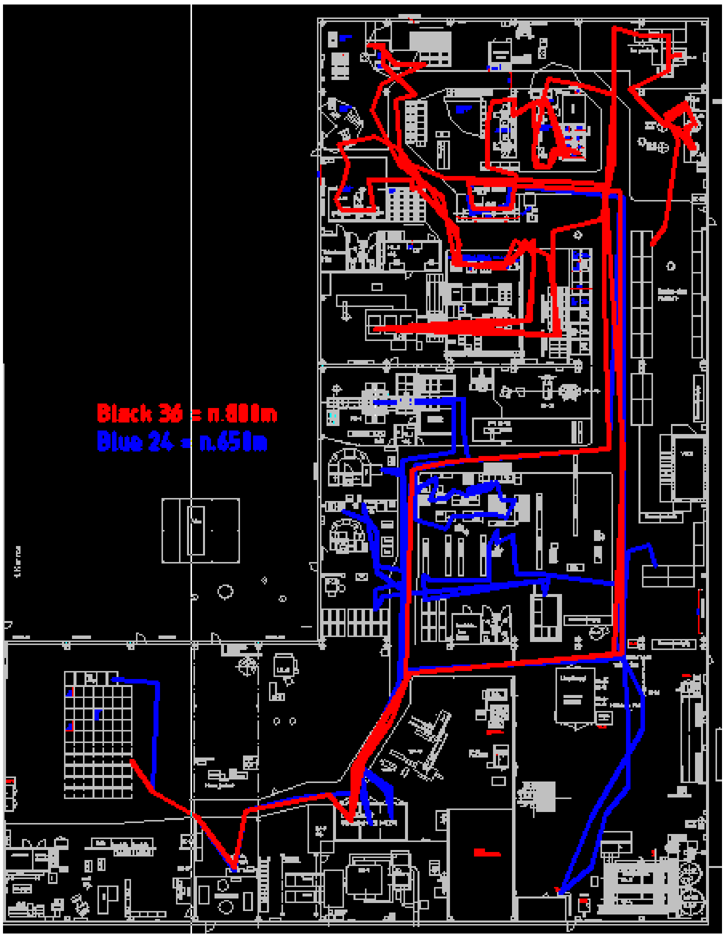
One remarkable point was that the resources which could be freed from the production could now be transferred to product development tasks and this part of the business could also increase the speed and effectiveness.

6.5 The New Layout

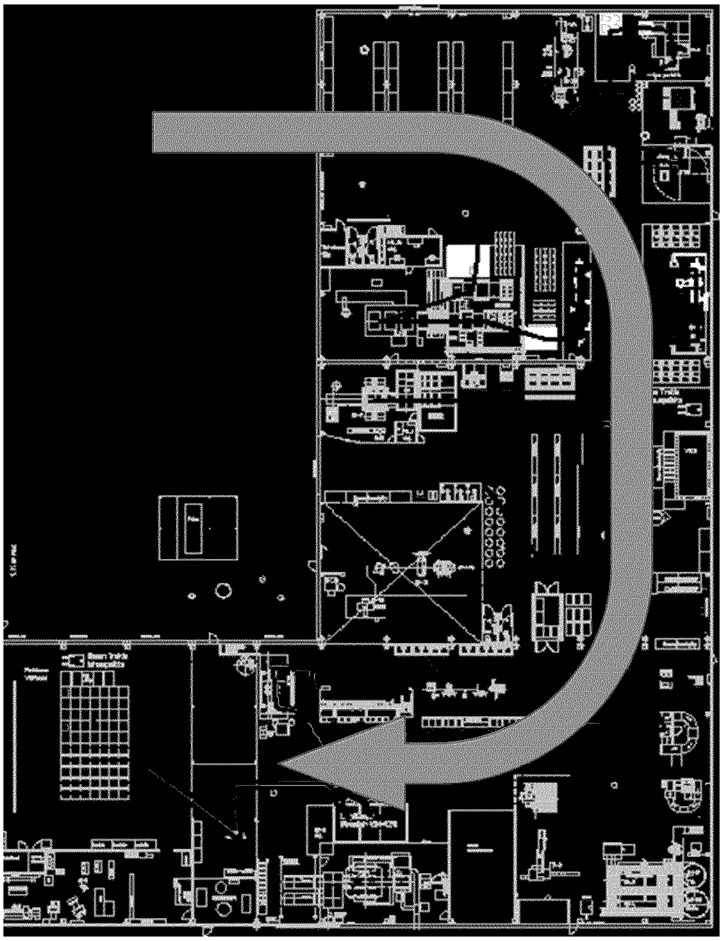
As a result of the VSM and spaghetti layout studies, a new layout was designed. Previously, the material flow (see pict. 14) did not work by Lean principles. All raw materials came into the factory in the middle of the production and this caused only a lot of unnecessary movement. A new layout was designed in a way that the production process would flow through the plant (see pict. 15).

The raw material stock was reduced by 30% by implementing new order levels. This made the raw material stock easier to follow and it reduced the amount of capital that was tied up to the raw material stock.

The difference between the old layout and the new layout can be seen by comparing picture 14 and picture 15. In pictures 14 and 15 a spaghetti diagram for two main products can be seen. A product called Black 36 is marked red and The blue is for Blue 24. Previously, it took approximately 800 meters for one Black 36 product to go through all process steps. By implementing a new layout this distance was reduced to 420 meters. For the other product, blue 24 it took previously approximately 650 meters and after the layout change it was reduced to 280 meters.



Picture 14, Old layout



Picture 15, New layout

6.6 5S

As stated in part 5.6 of this study, the 5S was fully implemented after the layout change. As a result of the 5S implementation, approximately 15 truck-loads of old material, tools, equipment, etc. was scrapped. This exercise set more space free for production and increased production capacity by removing or reducing unnecessary movement and searching of tools. Also, a clean and spacious work environment has removed lost time injuries completely (from Q1-Q3/2014).

7 FURTHER STUDY AND ACTIONS

7.1 Layout

The New layout is a set of compromises after compromises. A lot was achieved in a short time but a lot is still to be fixed or as it is stated in Lean-terms, improved. After the layout change, some improvements that have been done have reduced the blue 24 distance from 280 meters per piece to near in 200 meters per piece which is less than 1/3 of the original. Continuous improvement actions will bring new ideas to making the production more Lean every day. As an action, it is suggested for an action that the entire layout should be investigated constantly despite of what might happen to the product. New improved ways of working will come in future and for example the price of the robots has come down rapidly. The production line is still relying on movement which is mostly manual and this, as the price levels come down, will be one part of further study.

7.2 Cellular manufacturing and one-piece flow

Manufacturing still relies on batches after Lean implementation. The single piece flow has not become reality. Flow is created by using daily production levels for each workstation. It is suggested that the entire production moves towards pull production step by step, which would ease up time and resources form production management and supervisors when the production operator would start to manufacture by demand, not by daily target.

Also cellular manufacturing which would reduce throughput time is suggested. Cellular manufacturing, as a down-side, requires more resources and therefore the efficiency would need to be carefully determined before implementation.

7.3 Continuous improvement and PDCA

After the layout change, in six months, more than 100 improvement proposals have been made. This creates a core for PDCA or continuous improvement. On top of this, it is suggested that there should be a planned PCDA session annually which would aim to improve production or processes. This PDCA would be built on a structured way using tools like 8D or six sigma. These continuous improvement sessions would have a project plan, pointed resources and targets set in advance.

7.4 Validity and reliability

The validity of this study is based on the acquired information during the VSM. Most of the improvements were done by using common sense where the VSM was a very helpful tool. All changes were discussed with all stakeholders so that every aspect would be seen before the implementation. It is also important to understand that some changes need to be refined and the immediate effect might be something else that was originally planned. A lot of changes have been planned to take place simultaneously, which will raise some concerns about the overall effect.

The reliability of this study is based mostly on the gathered data during the VSM study. The VSM data was collected during one workday per one workstation. This data included most work tasks in a repeated mode. The start of the day and the end of the day was recorded only once and that can cause some deviation between planned and real life situation. The VSM study is a snapshot of how production is doing on one specific day by one production operator. For this reason the VSM was cross-checked with the operators' hour reports and there was only small deviation. Throughput data from the previous years was used to see how much throughput time could be improved.

All collected data that was compared to the previous data used averages and for that reason variance analysis would have been valid task. As a last further research action it is suggested that a process walk practice would be implemented to follow up how planned improvements have taken place and also to find out the variance of production process. The last part would be done by implementing six sigma tools and practices.

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APPENDIX 1

Arvovirtakartoitus

Vaihe / Havainto	[redacted]		[redacted]	Alkoi klo	Päättyi klo	Kesto	Kommentit

VSM mapping table